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BOSTON UNIVERSITY
GRADUATE SCHOOL

Dissertation

AN INTERFEROMETER METHOD OF DETERMINING WAVELENGTHS IN
THE H-D SPECTRUM


by
William Walker Bartlett

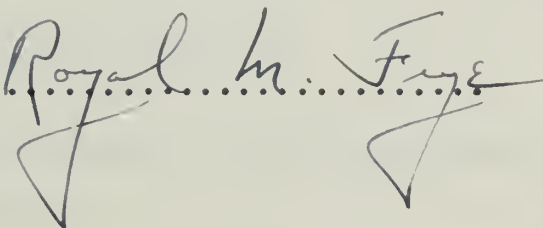
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Introduction

A great deal of work has been done in the measurement of the wavelengths of the spectral lines of almost every element in the periodic table. George R. Harrison¹⁾ has published a table which contains 100,000 wavelengths of the strongest lines of these elements. At the Spectroscopy Conference at the Massachusetts Institute of Technology in 1939 the representatives of large industrial concerns were quite unanimous in one point, namely the great desirability of such a wavelength table. The use of spectral lines in the quantitative and qualitative analysis of materials is very well known. The use of spectrum analysis for criminal investigation and for many branches of industry shows clearly the need for accurate wavelengths.

The method used by Harrison consists in superposing the spectrum of the standard Pfund iron arc on the spectrum of the element whose wavelengths are to be measured. Knowing the wavelengths of the standard iron lines one may then find the wavelengths of the element by a straight interpolation process. The wavelengths of the standard iron lines are determined by means of an interferometer. Harrison has developed automatic machinery to such an extent that one may obtain a photographic record of the wavelengths of all the spectral lines on a photo-

graphic plate within a half-hour after setting the plate in the machine. This may amount to 1000 or more wavelengths per hour. Contrasted with manual methods which require fifty or more hours to obtain the same results we see what an accomplishment this is. One wavelength investigator who had worked many years using the long-hand method said, "It's very nice, Harrison, but you have taken the romance out of wavelength determination."

Whatever romance there may have been in such determinations still remains in the interferometer method. There is at present no machine which will measure the diameters of the successive interference rings of each spectral line and carry out the necessary calculations for this type of wavelength determination.

The wavelengths of elements obtained by an interpolation method are only as accurate as the standards from which they are calculated. Thus it is necessary to have accurate standards. Molecular hydrogen is very rich in spectral lines. Measurement of these lines using iron lines as reference standards is apt to result in erroneous wavelengths due to the interference of many lines of one spectrum with the other. A more ideal method is the use of tertiary standards of hydrogen itself. The wavelengths of these tertiary standards may be calculated by an interferometer method

using iron lines as reference standards.

Gale, Monk, and Lee²⁾ made the first extensive interferometer measure in the molecular spectrum of hydrogen. Subsequent work in this spectrum has been done by Lacount and Hodgdon,³⁾ and by Combes⁴⁾ at Boston University. Combes worked in the region 5800A-4800A and he determined the wavelengths of twenty-five of the strongest H₂ lines therein. He used the standard Pfund iron arc as a comparison spectrum. He got remarkably consistent results but because he observed a different "plate constant" for the iron and hydrogen spectra there still remained some doubt as to the validity of the wavelengths.

The writer has made a check on Dr. Combes' values using an optical system somewhat different from his and has also made interferometer determinations of 18 lines in the spectrum of the deuterium molecule. This paper will be therefore divided into two parts; the first will explain the work done in checking Combes' values and the second will deal with the H-D spectrum.

REVIEW OF WORK OF PREVIOUS INVESTIGATORS

Interferometer measurements in the molecular spectrum of hydrogen have been made by Gale, Monk, and Lee, Lacount and Hodgdon, and Combes. The work of Gale, Monk, and Lee is quite extensive whereas that of the others is limited to wavelength ranges of roughly 1000\AA . Combes worked in the range $4800\text{\AA} - 5800\text{\AA}$ and in this dissertation the writer has made a check on Combes' determinations.

Part I

The Optical System

The optical system used for checking Dr. Combes' determinations of wavelengths in the molecular spectrum of hydrogen is somewhat similar to that used by Dr. Combes himself. He had an arrangement whereby he exposed almost continuously the light from his hydrogen discharge tube. At intervals of perhaps one hour he was obliged to swing a mirror in such a fashion that the light from a standard Pfund iron arc followed the same optical path that the hydrogen light did after leaving the discharge tube. The iron arc would be exposed 10 seconds or so and then the mirror would be swung out of the way again to let the hydrogen light through once more.

Dr. Combes found that his "plate constant" was not the same for the hydrogen and iron spectra. One reason for this, it was thought, was that the iron light and the hydrogen light did not strike the etalon plates for the same length of time or at the same time. Consequently, since the hydrogen source and the iron arc source struck the etalon plates with a different intensity (vastly different for this set-up), there was a different amount of heating of the plates which amounted to a varying plate separation.

It was thought advisable to expose the iron arc

and the hydrogen tube simultaneously and for the same length of time. First the iron arc was placed directly behind the tube with a lens to render the light from the iron arc parallel as it passed through the tube. This did not work very well in that only a small image of the arc was observed on the spectrograph slit while at the same time the light from the hydrogen tube itself formed a large image on the slit. In this arrangement the iron arc consisted of a small source 1.5 to 2 mm. in diameter since only the central portion of the arc had been taken; the rest of it being cut out by a series of diaphragms. It was noticed however that an extended source would give an image on the slit the same size as the image of the light from the hydrogen discharge tube itself. Thus it was merely necessary to change the small source to a large one.

This was done by allowing a magnified image of the iron arc to fall on the back window of the discharge tube. When the image had a magnification of about 10x, the central portion of the iron arc then constituted our desired extended source. Fig. 1 shows the optical system outside the grating room while Fig. 2 shows a top view of the grating room and the optical system within it.

Hydrogen (see Fig. 1) is formed electrolyti-

cally and is allowed to enter the discharge tube through drying tubes. The discharge tube is supplied with about 20,000 volts and 250 milliamps by transformer B. P is the Pfund iron arc the light of which passes through L_1 , strikes mirror M_1 , and forms a magnified image at D which is a diaphragm placed quite close to the back window of the discharge tube. G is a piece of ground glass used to diminish the intensity of the iron arc. The proper amount of oil rubbed on the surface of the ground glass allows the light to come through with the proper intensity. By experimenting a little one can make the light from the iron arc and that from the hydrogen discharge tube leave the discharge tube with approximately equal intensities.

L_2 and L_3 form a combination of lenses which give an image of the source at E, the front surface of the etalon (shown in Fig. 2). The light then goes through the etalon, strikes the concave mirror M_3 and is directed to slit S. S is the slit of a 30' Littrow spectrograph which is suspended by springs and which also rests lightly against sponges so any small vibrations are damped out quite rapidly. L_4 , G_r and P_L are the lens, grating, and plateholder of the Littrow mount. T_1 and T_2 are thermometers indicating the temperature of the grating room. The outer room is equipped with a

thermostat which keeps it at a fairly constant temperature. The temperature of the inner room does not vary more than a few tenths of a degree throughout an exposure.

The Optical System

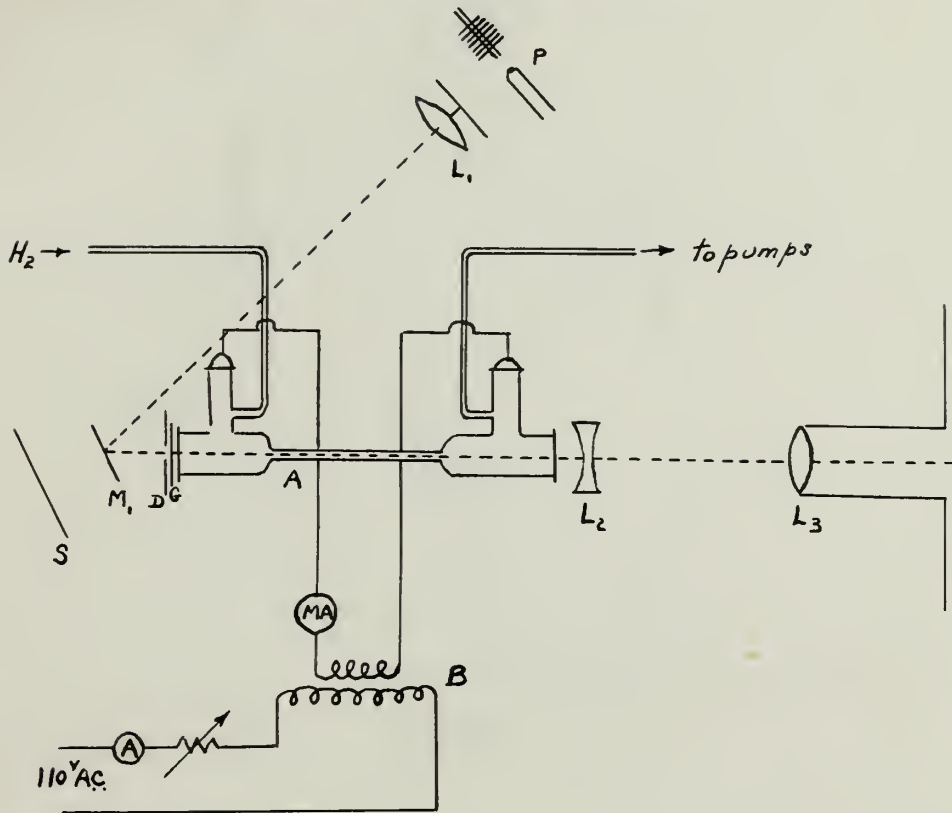


Fig 1.

- A Discharge Tube
- P Pfund Arc
- L₁ Lens to give magnified image at D
- L₂, L₃ Lens System
- B High Voltage Transformer
- S Viewing Screen for image of Pfund Arc
- M Mirror
- D Diaphragm
- G Ground glass



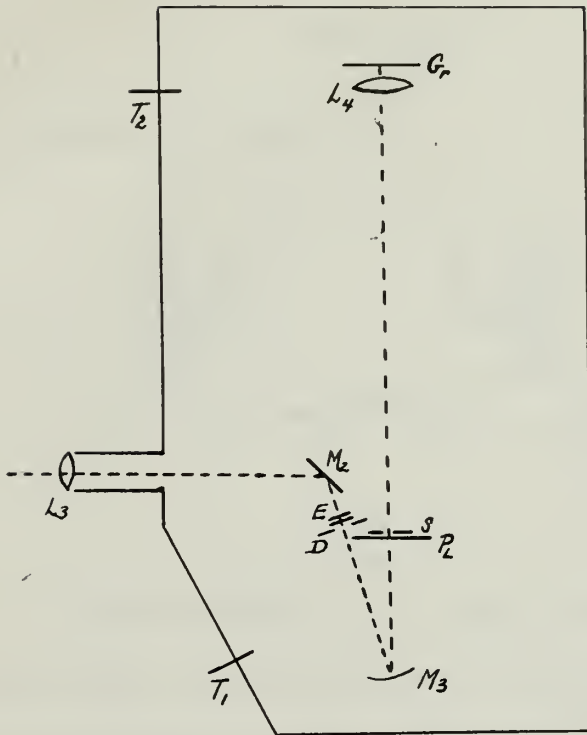


Fig 2.

- L_3 Lens
- M_1, M_2 Mirrors
- E Etalon
- S Slit of Spectrograph
- L_4 Lens
- G_r Plane Grating
- P Plate Holder
- T_1, T_2 Thermometers
- D Diaphragm

SOURCES

a. The Discharge Tube.

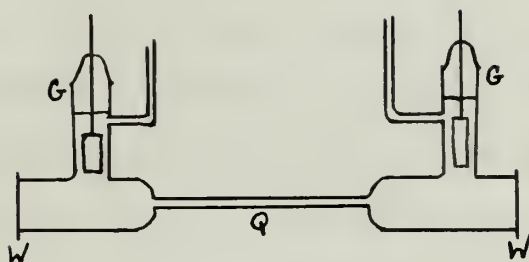


Fig. 3

The discharge tube (Fig. 3) has the windows W at both ends, the cylindrical platinum electrodes C and the two ground joints G which may be removed in case anything goes wrong with the electrodes. The capillary Q is small (0.8 cm. diam.) so as to concentrate the discharge. When the tube is running it is water cooled and a box for holding the water surrounds it. The tube may be removed from the box but this necessitates breaking glass joints with subsequent glassblowing when the tube is to be replaced. In order to bring out a strong secondary spectrum of hydrogen it is necessary to coat the inside of the capillary Q with a catalytic agent such as platinum. This capillary was coated with a liquid platinum compound and this was heated until the platinum coated the walls of the tube forming a mirror-like surface. The hydrogen was intro-

duced into the discharge tube through drying tubes containing desichlora, a compound having a greater absorbing power for water than ordinary calcium chloride. For evacuation of the system a Cenco Hyvac pump was used in connection with a Langmuir diffusion pump and mercury trap. Dry ice and acetone were used as refrigerants for the mercury trap. A McLeod Gauge served as a pressure indicator. The pressure of hydrogen for best running conditions is about 300 microns of mercury. Running the tube at excessively high or extremely low pressures is very apt to damage the tube seriously.

b. The Pfund Arc.

The Pfund arc is an arc which is to be run according to certain specifications. The upper terminal is about 5 mm. in diameter and is surrounded by a set of vanes which tend to cool it. The lower terminal is a rod about one-half inch in diameter which has a cup at the top of it to hold a bead of iron. The running conditions should be as follows: 220 volts with lower electrode positive, amperage preferably below 4 amperes, electrode separation about 15 mm. with upper electrode extending about 3 mm. below cooler. With the electrodes separated 15 mm., the central 1.5 mm. of the arc should be used for exposing purposes. These conditions were followed closely every time an exposure was taken.

Since the exposures ran for six hours it was necessary, at intervals of about an hour, to clean and readjust the iron arc.

TEMPERATURE CONTROL OF THE GRATING ROOM

The grating room is a room separated and insulated from the source room. By keeping the temperature of the source room constant to within a few degrees, the temperature of the grating room is kept constant within one or two tenths of a degree. This was accomplished by the use of a thermostat consisting of a mercury column which at a certain fixed temperature closes a relay circuit, which in turn closes a circuit on a 110^v line which opens a shutter by the aid of an electromagnet. With the opening of the shutter, a fan is turned on which draws air in from the outside. As soon as the temperature drops far enough the mercury column drops and the relay circuit is broken. The shutter is then closed again by means of an attached spring. The mercury column may be set to complete the relay circuit at any reasonable temperature. The average temperature of the room when the tube and iron arc were not running was chosen. This arrangement worked very well during the winter when the air outside was cold enough to lower the temperature of the room. Since all my exposures were taken during the winter and early spring the system was adequate.

and had been the only one of the kind in the world.

The first of these was the discovery of the gold mine at Sutter's Fort, in 1848. This discovery led to the great gold rush of 1849, which brought thousands of people to California. The second was the discovery of the gold mine at Comstock, in 1875. This discovery led to the great silver rush of 1876, which brought thousands of people to Nevada. The third was the discovery of the gold mine at Lead, in 1876. This discovery led to the great lead rush of 1877, which brought thousands of people to Missouri.

The fourth was the discovery of the gold mine at Cripple Creek, in 1891. This discovery led to the great gold rush of 1892, which brought thousands of people to Colorado. The fifth was the discovery of the gold mine at Homestake, in 1898. This discovery led to the great gold rush of 1899, which brought thousands of people to South Dakota.

The sixth was the discovery of the gold mine at Butte, in 1899. This discovery led to the great gold rush of 1900, which brought thousands of people to Montana. The seventh was the discovery of the gold mine at Lead, in 1901. This discovery led to the great lead rush of 1902, which brought thousands of people to Missouri.

The eighth was the discovery of the gold mine at Cripple Creek, in 1902. This discovery led to the great gold rush of 1903, which brought thousands of people to Colorado. The ninth was the discovery of the gold mine at Homestake, in 1904. This discovery led to the great gold rush of 1905, which brought thousands of people to South Dakota.

The tenth was the discovery of the gold mine at Butte, in 1905. This discovery led to the great gold rush of 1906, which brought thousands of people to Montana. The eleventh was the discovery of the gold mine at Lead, in 1906. This discovery led to the great lead rush of 1907, which brought thousands of people to Missouri.

The twelfth was the discovery of the gold mine at Cripple Creek, in 1907. This discovery led to the great gold rush of 1908, which brought thousands of people to Colorado. The thirteenth was the discovery of the gold mine at Homestake, in 1908. This discovery led to the great gold rush of 1909, which brought thousands of people to South Dakota.

The fourteenth was the discovery of the gold mine at Butte, in 1909. This discovery led to the great gold rush of 1910, which brought thousands of people to Montana. The fifteenth was the discovery of the gold mine at Lead, in 1910. This discovery led to the great lead rush of 1911, which brought thousands of people to Missouri.

The sixteenth was the discovery of the gold mine at Cripple Creek, in 1911. This discovery led to the great gold rush of 1912, which brought thousands of people to Colorado.

PROCEDURE

For most efficient work, the optical system should be such that the light from the source strikes the grating centrally and just fills it. The method used to "line up" the source and the grating will now be given. Referring to Figs. 1 and 2, let us focus our attention on lens L_4 . L_4 is about one foot in front of the grating and is located centrally with respect to it. By this we mean that light traversing the lens along its axis strikes the grating centrally. A small circular diaphragm was placed at the center of L_4 between L_4 and the grating and the light from a small-wattage bulb was allowed to shine through the lens. The concave mirror M_3 already placed at its focal length from slit S was then raised or lowered and moved laterally until the light coming through slit S struck M_3 centrally. The only further adjustment on M_3 now could be a rotation about a vertical and a horizontal axis. Adjustment of M_2 and M_3 was then made such that the light reflected from M_3 traversed etalon E and also the capillary of the discharge tube centrally. Mirror M_1 was then rotated so that the light traversed L_1 centrally then the crater of the Pfund arc could be placed behind L_1 at the point where our light came to a focus. All mirrors

were then clamped in position.

Using a source on the "source" side of the apparatus it was not a difficult process to adjust diaphragm D (next to the etalon) so that the light just filled grating G_r symmetrically. The diaphragm D is mounted so that it can be moved laterally or rotated about a horizontal axis. The lenses L_2 and L_3 were adjusted so that an image of uniform intensity was formed on the first plate of etalon E. A uniform interferometer pattern was then obtained at slit S. The plateholder P_L had been placed in focus previously by the "slant plate" method and also the method of parallax. In the parallax method a fine wire is suspended vertically at various points coplanar with the plateholder rails. The plateholder is then moved by means of screws until no parallax is noticed between spectral line and wire. When this situation exists, the plateholder is in focus.

The method for determining wavelengths from an interferometer pattern necessitates the measurement of the diameters of successive rings for each pattern. Projecting the interferometer pattern upon the slit would give, on the photographic plate, a series of arcs rather than a ring system for each spectral radiation. If the pattern struck the slit symmetrically, the distance between corresponding arcs on both sides of the

central spots would be the ring diameters. Before each exposure the etalon was adjusted for the above mentioned symmetry. For a pattern of like intensity on both sides of the central spot it was necessary for the interferometer plates to be parallel. To check on this parallelism, one shines light from a mercury lamp upon the etalon. One observes the interferometer pattern and moves his head from side to side. If the plates are not parallel the rings expand or contract. One then adjusts the plates by means of screws until the pattern does not change with the motion of the head. The plates are then parallel.

A final adjustment for the symmetry of the pattern on the slit is made by using an ocular at the plateholder. The ocular views the pattern as it comes from the grating and the etalon may be rotated very slightly until one sees the series of arcs representing diameters rather than chords. This procedure may be carried out quite easily if a wide slit is used. When the adjustment has been made the slit (bilateral) may be adjusted to the proper width for exposure. The best slit width for this work was found to be about .055 mm.

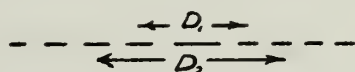
Using this set-up, ten interferometer plates were taken. Of the ten, the five best were used for wavelength determination. The method used is adequately described

by Combes.

The photographic plates used were Eastman 103-D. Exposure times were from six to eight hours. Plates were developed for five minutes in D-19. All patterns were measured on a comparator at the Massachusetts Institute of Technology. The measurements were recorded by a counter and camera arrangement on a photographic film.

WAVELENGTH DETERMINATION

The method for calculating the wavelengths will be given briefly here. Below is a sketch of a typical interferometer pattern of a spectral line.



D_1 , D_2 are distances which represent the diameters of the interference rings. To determine these diameters the position of each of the "spots" was measured with an accurate comparator at the Massachusetts Institute of Technology. From an average of the measurements on these spots the diameters of the rings could be obtained merely by subtraction. The values D_n were then squared and the difference between successive D_n^2 's were recorded. According to theory ΔD_n^2 is a constant for a particular line but increases with the wavelength. $\frac{\Delta D_n^2}{\lambda}$ is a constant for the entire plate and the reciprocal of this is called the plate constant $K\lambda$. The average value for $K\lambda$ obtained from all the lines on the plate is then divided by each individual wavelength to obtain what may be called K_λ for a particular line. K_λ is then multiplied by each D_n^2 and from theory $K_\lambda(D_n^2 - D_{n-1}^2) = 1$. One finds that the values for $K_\lambda D_n^2$ differ by just an integer. For example: three values of $K_\lambda D_n^2$ for a particular line may be 5.717,

4.719, 3.718. The fraction accompanying these integers is what is known as the fractional order of interference of the interferometer pattern and is denoted by the symbol ϵ . The relation between the order of interference and the wavelength of the spectral line is given by $p = \frac{2t}{\lambda}$ where $2t$ is twice the separation of the interferometer plates; p is the order of interference and consists of an integral part and the fractional part ϵ .

Knowing $2t$ approximately one may find it exactly by the use of standard wavelengths. Having obtained ϵ for each standard by the method outline above and also the integral order of p from the approximate value of $2t$, one may, by changing p by one or two units for each of the standards, find a value of $2t$ which will fit each of them. This exact value of $2t$ is then used to determine accurate wavelengths of the other spectral lines on the plate whose approximate values may be known to an accuracy of 0.01\AA^0 .

An actual calculation of the wavelength of one hydrogen line is as follows. The wavelength is known to be approximately 5303.100\AA^0 . The diameters of the rings are obtained by measuring on a comparator the position of each arc of the interferometer pattern. These are recorded in the first two columns.

Ring No.	One Side	Other Side	Diam.	$\frac{\text{Diam.}^2}{\Delta D_n^2}$	ΔD_n^2	$\text{Av } \Delta D_n^2$
5	73.671 mm.	107.513	33.842	1145.281	233.8	
4	75.473	105.698	30.225	913.551	228.0	
3	77.512	103.697	26.185	685.654	233.6	230.9
2	79.924	101.185	21.261	452.030	228.3	
1	83.017	97.975	14.958	223.742		

Ring No.	$\frac{\lambda}{\Delta D^2}$ or $k\lambda$	$\frac{K\lambda}{\lambda} = K_\lambda$	$K_\lambda D_n^2$	ϵ	$p = \frac{2t}{\lambda}$	actual p	$\lambda = \frac{2t}{p}$
5			4.9847				
4	22.967	.0043524	3.9761	0.9772	35004	35004.977	5303.0998A°
3			2.9842				
2			1.9674				
1			0.9738				

The "2t" is obtained exactly from the lines used as standards. For this exposure

$$2t = 18.563489 \text{ mm.}$$

RESULTS

Using the above-described optical system, the wavelengths of twenty-two of the strongest lines calculated by Dr. Combes were checked by the writer. In all cases the "plate constant" was the same for both hydrogen and iron lines. The writer's values, the average of which will be given on a separate sheet, are in good agreement with those of Dr. Combes. We both feel that our values for the hydrogen wavelengths are good to 0.001\AA which is all that may be claimed for the iron standards in this wavelength range. This being the case, it was decided to use these hydrogen "standards" for the measurement of lines in the H-D spectrum by the interferometer method. This work will be described in Part II.

Comparison of Dr. Combes' and my values for
certain lines in the spectrum of molecular hydrogen.

Intensity	Dr. Combes	Bartlett	Combes - Bartlett
10	4934.241	.240	+1
8	4973.313	.312	+1
10	5013.032	.032	0
9	5030.366	.367	-1
9	5039.829	.829	0
9	5055.094	.094	0
7	5113.127	.128	-1
7	5256.612	.613	-1
9	5303.100	.100	0
7	5355.912	.910	+2
10	5388.161	.160	+1
10	5419.891	.890	+1
10	5481.080	.078	+2
10	5505.511	.510	+1
10	5537.461	.461	0
10	5597.636	.637	-1
10	5612.545	.545	0
9	5655.747	.749	-2
10	5728.546	.546	0
9	5775.043	.043	0
8	5806.095	.094	+1
10	5822.759	.758	+1

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DEPARTMENT OF CHEMISTRY

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PART II

Introduction

The work described in Part I was done for the purpose of checking Dr. Combes' wavelengths in the hydrogen secondary spectrum. For this work the Pfund Iron Arc was used for a comparison spectrum and was run simultaneously with the hydrogen discharge tube. In a small room the heating produced by a Pfund arc run at 220^v and 3.5^a is considerable. The room, however, was kept at quite a constant temperature during the winter by means of the thermostatic arrangement previously described. During the summer, however, the outside air was warmer than that of the room in which the exposures were to be made so that the thermostatic arrangement was of no benefit.

It was felt that the hydrogen wavelengths obtained independently and with different optical systems by Dr. Combes and by the writer were correct to 0.001A°. The wavelengths of the iron standards have this same probable error so it was decided to dispense with the Pfund arc and use Combes' wavelengths for hydrogen as standards for obtaining deuterium tertiary standards. Since the walls of the discharge tube and especially the platinum coating of the capillary were impregnated with ordinary hydrogen, any exposure of a supposedly deuterium discharge would be accompanied by a considerable amount of hydrogen. This

proved to be the case and indeed a great many hours of running the discharge and flushing with deuterium were needed before anything but ordinary hydrogen was noted on the spectral plate.

Lacount had previously obtained grating plates of the deuterium secondary spectrum as well as some of a spectrum between that of pure hydrogen and pure deuterium. This spectrum is called the H-D secondary spectrum. Use of tertiary H-D standards facilitates the accurate determination of the wavelengths of the lines in the H-D spectrum. About half of the hydrogen lines which Combes calculated for standards appear in the H-D spectrum and these were used as standards from which tertiary H-D standards could be calculated. The calculation of these tertiary standards is the object of the work done for Part II of this report.

APPARATUS

The optical system for the H-D program is the same as that for hydrogen except that no Pfund arc was used with the H-D discharge. The electrodes used for the hydrogen discharge of Part I were cylindrical and made of platinum. Each was suspended vertically by a tungsten wire spot welded to it. On several occasions these electrodes would get hot enough to melt the spot welded connection and fall from their supports. This not only spoiled the exposure but also caused a delay until the electrodes could again be soldered into place.

Since long exposures would be necessary for the H-D program, it seemed wise to have more substantial electrodes. After some consideration electrodes of the type pictured below were made.

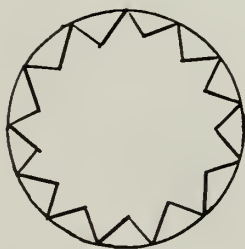


Fig. 4

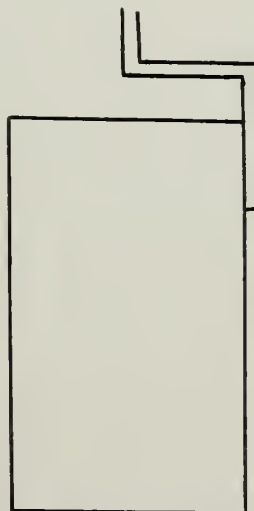


Fig. 5

Fig. 4 shows an end view of the cylindrical aluminum electrode with corrugated inner lining for greater discharge surface. Fig. 5 shows a cross-section of the electrode and the aluminum bar riveted to it as a means of support. These electrodes proved to be much better than the platinum ones in that they did not once cause any trouble.

Deuterium gas was introduced into the discharge tube from a flask containing the gas. The etalon used had a plate separation of approximately 9.282 mm. With the exception of the gas source, the apparatus for the H-D program is the same as that used for the hydrogen program.

PROCEDURE

The wavelength region for the H-D program is the same as that for the hydrogen program of Part I, namely $5800 - 4800\text{\AA}$. Consequently there was no need of any re-focusing of the plateholder. Before each exposure, however, a careful check was made on the optical system to be sure that the grating was filled properly with light. The discharge tube was run probably twenty hours at a pressure of 400 microns before the H-D spectrum could be obtained. This was due to the hydrogen absorbed in the platinum catalyzer coating on the capillary and also on the walls of the discharge tube. After the discharge tube had been run to such an extent that the H-D spectrum came out as strong on the photographic plate as the hydrogen spectrum, interferometer spectrum plates were taken.

Each exposure for the H-D was eight hours, a deuterium pressure of 350μ , a voltage of 16000V and a current of 250 ma. Plates were developed in D-19 for five minutes at a temperature of 18°C . Eight interferometer plates were exposed and five of these were suitable for measurement and calculation.

The patterns on these plates were measured on a comparator at Massachusetts Institute of Technology. The wavelengths of the spectral lines were calculated

using the method of an earlier part of this paper. A table showing the results obtained from these five plates is given below.

Table showing wavelengths calculated from five different
interferometer plates.

<i>Integral Part (Å)</i>	<i>Fractional</i>						Av dev
	E13	E10	E15	E12	E16	Av	
4848	5163	5153	5139	5131	5156	5148	.0011
4904	1535	1515	1507	1527	1524	1521	.0009
4916	2023	2003	2003	1983	2000	2002	.0009
*4934	2431	2420	2431	2423	2409	2422	.0006
*4973	3121	3139	3121	3146	3110	3127	.0012
4990	6890	6891	6891	6877	6889	6888	.0004
*5013	0352	0348	0352	0330	0340	0344	.0008
*5039	8301	8298	8292	8286	--	8294	.0005
5052	0724	0703	0703	0699	0733	0712	.0013
*5055	0949	0939	--	0931	0945	0941	.0005
*5113	1253	1278	1259	1266	1296	1270	.0013
*5303	1016	0992	0999	0999	1009	1003	.0008
5352	6716	6729	6710	6737	6740	6726	.0011
5377	4844	4851	4836	4845	4847	4844	.0004
5381	8980	8957	8990	8991	9013	8986	.0014
*5419	8899	8900	8913	8905	8913	8906	.0005
5463	0128	0116	0161	0119	0143	0133	.0015
5478	4623	4595	4628	4645	4628	4624	.0012
*5481	0772	0734	0773	0763	0760	0760	.0011
5488	5896	5920	5902	5897	5899	5903	.0007
*5505	5105	5088	5127	5104	5149	5115	.0019
5525	0374	0361	0349	0362	0394	0368	.0013
5537	4601	4581	4611	4595	4581	4594	.0010
5563	4743	4771	4752	4742	4747	4751	.0008
5582	4443	4442	4450	4434	4450	4444	.0005
*5612	5438	--	5444	5445	5446	5443	.0002
5624	8583	8578	8592	8605	8605	8593	.0010
5645	2905	2911	2931	2888	2924	2912	.0012
*5655	7463	7504	7457	--	7462	7472	.0012
5690	0877	0850	0827	0841	0878	0855	.0018
*5728	5462	5454	5463	5461	5449	5458	.0006
							<hr/>
							.00093

*Hydrogen standards.

RESULTS

Below is a tabulation of the H-D lines which I offer as tertiary standards for future work.

\AA	<u>Intensity</u>
4848.515	3
4904.152	3
4916.200	10
4990.689	5
5052.071	4
5352.673	2
5377.484	3
5381.899	3
5463.013	5
5478.462	9
5488.590	5
5525.037	2
5537.459	8
5563.475	4
5582.444	8
5624.859	5
5645.291	6
5690.086	5

These values represent an average of five calculations for each line and have a probable error of 0.001\AA^0 .

ABSTRACT

The work presented in this paper was carried out to serve two purposes. The first was to check the values of the tertiary standards in the molecular spectrum of hydrogen calculated by Dr. Combes in the range 5900\AA° to 4900\AA° . The second was to calculate tertiary standards in the H-D spectrum (a spectrum given by the H-D molecule consisting of an atom of hydrogen linked with an atom of deuterium). The tertiary standards may be used for calculation of ^{the} wavelengths of the lines in the H-D spectrum.

The apparatus used for this work consisted of a Fabry-Perot interferometer with a plate separation of approximately 9.282 mm. crossed with a plane reflection grating in a Littrow mounting. A standard Pfund iron arc was used for obtaining reference standards. The reason for checking Dr. Combes' work was because he had different optical paths for his standard iron arc and the hydrogen discharge. Dr. Combes obtained remarkably consistent results but there remained some doubt as to their validity since the "plate constant" for his iron lines differed from that of his hydrogen lines. The check was made using practically the same optical path for the iron arc as for

the hydrogen. In addition the Pfund arc was exposed continuously along with the hydrogen discharge in this work while Dr. Combes exposed his iron arc only at intervals.

The same standard iron lines employed by Dr. Combes were used by the writer. Five interferometer plates were obtained and Dr. Combes' values were found to agree with the writer's to 0.001A. Plate constants were found to be the same for hydrogen and iron in all cases. A comparison of Dr. Combes' values and my average values will be given at the end of the abstract. This work was done in the winter and there was no difficulty in keeping the temperature of the room surrounding the grating room constant within a few degrees. This was accomplished by using a thermostat control which would draw cold air into the laboratory from outside the building whenever the temperature exceeded the normal room temperature. Although each exposure took six to eight hours the temperature of the inner, that is the grating, room remained constant to 0.1°C throughout the exposure.

The interferometer patterns were measured on a comparator at the Massachusetts Institute of Technology and the calculations of the wavelengths were made according to the method described in this paper. Briefly the method is as follows: Measure the diameters of successive rings and square these values. From these values find

ΔD_n^2 , the difference in the squares of the diameters of successive rings. For any particular spectrum line the difference is a constant. The approximate wavelength of the line divided by ΔD_n^2 , ~~is~~ called the "plate constant", is a constant for each line on the plate and is designated by $K\lambda$. This " $K\lambda$ " is found for each line, the wavelength of which is to be calculated and the average of them is divided by the wavelength of each line to get K_λ for each line. K_λ is then multiplied by each D_n^2 of one interferometer pattern. When this is done a set of numbers is obtained which differ by an integer for any two successive rings. The fractional part of these numbers is the fractional order of interference for the spectral line. From an approximate value of the separation of the etalon plates, one may obtain the order of interference from the relation $p = 2t/\lambda$. Using the fractional order of interference calculated previously and the wavelengths of the standard iron lines one can find the exact value of t , the separation of the etalon plates. Then for each unknown line the wavelength may be found by the relation $\lambda = 2t/p$.

Calculation of tertiary standards in the H-D secondary spectrum was carried out using Dr. Combes' hydrogen tertiary standards rather than those of the standard Pfund arc. There are two reasons for this: first, the check on Dr. Combes' wavelengths, made by using a different optical

K'_λ
 K_λ

set-up, gave every indication that his values are correct to 0.001A which is all that can be claimed for the standard iron lines. Second, the Pfund arc running at 220^V and 4^A steadily for eight hours produces considerable heating. In the summer-time the air outside the laboratory which was used in the winter for cooling is warmer than any reasonable operating temperature. Thus dispensing with the Pfund arc makes constancy of temperature just so much easier. In the course of eight hours operation under summer conditions, the temperature of the grating room remained constant to within a few tenths of a degree.

With the exception of the Pfund iron arc the apparatus for this program was the same as for the hydrogen program. Eight interferometer plates were taken, each of about eight hours exposure and five of these were considered fit for calculation of tertiary standards. The H-D discharge was operated at 16,000 volts and 0.240 amps with a gas pressure of about 350 microns. The wavelength range is 5900A to 4900A. Eighteen lines, fairly intense and approximately evenly spaced were selected for calculation as tertiary standards. Thirteen of the strongest lines of hydrogen, calculated by Dr. Combes and later checked by the writer, were used as reference standards. The results are tabulated below. The probable error of ~~each wavelength~~ is 0.0009A.

Comparison of Dr. Combes' and my values for
certain lines in the spectrum of molecular hydrogen.

<u>Intensity</u>	<u>Dr. Combes</u>	<u>Bartlett</u>	<u>Combes - Bartlett</u>
*10	4934.241	.240	+1
*8	4973.313	.312	+1
*10	5013.032	.032	0
9	5030.366	.367	-1
*9	5039.829	.829	0
*9	5055.094	.094	0
*7	5113.127	.128	-1
7	5256.612	.613	-1
*9	5303.100	.100	0
7	5355.912	.910	+2
10	5388.161	.160	+1
*10	5419.891	.890	+1
*10	5481.080	.078	+2
*10	5505.511	.510	+1
*10	5537.461	.461	0
10	5597.636	.637	-1
*10	5612.545	.545	0
*9	5655.747	.749	-2
*10	5728.546	.546	0
9	5775.043	.043	0
8	5806.095	.094	+1
10	5822.759	.758	+1

*Lines used as standards for H-D calculations.

RESULTS

Below is a tabulation of the H-D lines which I offer as tertiary standards for future work.

<u>Wavelength</u>	<u>Intensity</u>
4848.515	3
4904.152	3
4916.200	10
4990.689	5
5052.071	4
5352.673	2
5377.484	3
5381.899	3
5463.013	5
5478.462	9
5488.590	5
5525.037	2
5537.459	8
5563.475	4
5582.444	8
5624.859	5
5645.291	6
5690.086	5

These values represent an average of five calculations for each line and have a probable error of $0.001A^0$.

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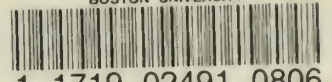
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AUTOBIOGRAPHY

William Walker Bartlett, son of James H. and Martha M. Bartlett, was born in Revere, Mass., January 4, 1912. He was graduated from the Coddington School in Quincy, Mass., in 1926, the Quincy High School in 1930, and ^{the} Massachusetts Institute of Technology in 1934 receiving the degree of Bachelor of Science at that time. In 1935 he was awarded the degree of Master of Science by the Massachusetts Institute of Technology. From 1936-1938 he was a teaching fellow at Massachusetts Institute of Technology and from 1938 - 1940 a teaching fellow at Boston University.



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